

REPORT No. 576

AIRCRAFT ACCIDENTS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D. C., June 22, 1936.

GENTLEMEN:

As a result of the recent rapid advances in aeronautics, the need has arisen for the revision of Technical Report No. 357 "Aircraft Accidents—Method of Analysis" in which is presented an analysis method that has been for a number of years the standard method used by the War, Navy, and Commerce Departments. Since the publication of this report questions of interpretation of some of the definitions have arisen and incidents have occurred for which the specified classifications seemed inadequate. A revision of the report has therefore been prepared by the Committee on Aircraft Accidents in order to meet these conditions.

The revision of the report was conducted at a series of thirteen meetings, the first of which was held on October 30, 1935. At these meetings the form of the analysis chart and the classifications shown on the chart were carefully considered, as well as the definitions.

In accordance with resolution adopted at a meeting of the Committee on Aircraft Accidents held this date, I have the honor to recommend that the attached report be published as a technical report of the National Advisory Committee for Aeronautics, to supersede Technical Report No. 357.

Respectfully,

COMMITTEE ON AIRCRAFT ACCIDENTS,
EDWARD P. WARNER, *Chairman.*

THE EXECUTIVE COMMITTEE
National Advisory Committee for Aeronautics
Washington, D. C.

REPORT No. 576

AIRCRAFT ACCIDENTS METHOD OF ANALYSIS

Report prepared by Committee on Aircraft Accidents

INTRODUCTION

PURPOSE AND HISTORY

This report is a revision of Technical Report No. 357, prepared by the Committee on Aircraft Accidents and published in 1930. The original report of the National Advisory Committee for Aeronautics on the analysis of aircraft accidents, of which Report No. 357 was the first revision, was prepared by a Special Committee on the Nomenclature, Subdivision, and Classification of Aircraft Accidents, and issued as Technical Report No. 308 of the National Advisory Committee for Aeronautics. The special committee was organized by the National Advisory Committee for Aeronautics in response to a request dated February 18, 1928, from the Air Coordination Committee, which consisted of the Assistant Secretaries for Aeronautics in the Departments of War, Navy, and Commerce. The request of the Air Coordination Committee was made "in order that practices used may henceforth conform to a standard and be universally comparable." The task of the special committee was, therefore, to prepare a basis for the classification and comparison of aircraft accidents, both civil and military.

The report of the special committee was approved by the Executive Committee of the National Advisory Committee for Aeronautics on October 3, 1928, and on recommendation of the National Advisory Committee the method of analysis outlined in the report was adopted for official use by the War, Navy, and Commerce Departments. As a result of recommendation of the special committee, a standing Committee on Aircraft Accidents was established for the consideration of questions regarding interpretation of the report and suggestions as to changes, and of such other questions relating to aircraft accidents as might arise from time to time.

Since the publication of the original report, the practical value of the method of accident analysis has been definitely proved by its use in the War, Navy, and Commerce Departments. However, during the first 2 years questions of interpretation of some of the definitions arose and incidents occurred for which the

specified classifications seemed inadequate. In order to meet these conditions Report No. 357 was prepared by the Committee on Aircraft Accidents. The recent rapid advances in aeronautics have resulted in the need for further revision, and this report has accordingly been prepared to supersede Report No. 357.

The membership of the Committee on Aircraft Accidents is as follows:

Representatives of the National Advisory Committee for Aeronautics:

Hon. Edward P. Warner, Chairman.
Dr. George W. Lewis.

Representatives of the Army Air Corps:

Capt. Lowell H. Smith, United States Army.
Captain E. V. Harbeck, United States Army.

Representatives of the Bureau of Aeronautics of the Navy:

Lt. Comdr. A. O. Rule, United States Navy.
Lt. S. B. Dunlap, United States Navy.

Representatives of the Bureau of Air Commerce:

Mr. Jesse W. Lankford.
Mr. J. T. Shumate.

GENERAL CONSIDERATIONS

DEFINITION OF AN AIRCRAFT ACCIDENT

An aircraft accident is an occurrence which takes place while an aircraft is being operated as such, as a result of which a person or persons are injured or killed or the aircraft receives appreciable or marked damage as a result of a failure of the aircraft structure or engine or through the forces of external contact, or through fire. For the purpose of analysis an aircraft is considered as "being operated as such" from the time the pilot or passengers board the aircraft with the intention of flight until such time as the pilot and passengers disembark from the aircraft upon completion of flight.

A collision of two or more aircraft should be analyzed and reported statistically as one accident. It is appreciated that in some cases, as where a collision involves two aircraft of different services, it will necessarily appear in two separate accident reports and that a certain amount of duplication in tabulation will inevitably be involved. In such a case each service involved will credit to its own account only those personnel injuries or fatalities occurring in the aircraft for which it is individually responsible.

AIRCRAFT ACCIDENT ANALYSIS FORM

In drawing up the aircraft accident analysis form and the accompanying definitions the committee had in mind the frequency rate of accidents from the various causes, the logical lines along which studies should be conducted, and the ease with which these studies can be made from this chart. It is recognized that to make a detailed study of accidents due to any one cause a further subdivision may be necessary. However, if all accidents are classified according to this chart the major causes can be easily determined and further investigation can be readily carried out for the purpose of eliminating these causes.

It was also recognized, in working out this chart, that the division of immediate causes between personnel and material as set forth in the chart and definitions was more or less arbitrary, since all defects of aircraft can in the last analysis be attributed to errors of personnel, whether in operation, inspection, maintenance, manufacture, or design. Since the purposes of the accident study seemed to be best served by drawing attention to defects of material, even though traceable ultimately to personnel errors, the line between personnel and material in the immediate causes was drawn at the operating or maintenance personnel of the aircraft. In other words, under the main heading "Personnel" there are included only those accidents for which personnel engaged in the operation or maintenance of the aircraft are responsible. Accidents due to material failure are classified under "Material" even though personnel charged with design, construction, or overhaul may be held responsible for the failure. Errors due to personnel other than those immediately accessory to the operation of the aircraft are shown in the "Underlying causes" or "Cross analysis", as set forth hereinafter, rather than in the main headings of immediate causes.

The plan as drawn up by the committee is not in any sense final or complete, but is presented to provide a working basis for the study of aircraft accidents from all sources.

WEIGHTING OF ACCIDENTS

Where two or more factors cause an accident, part will be charged to each; for example, in the case of an avoidable accident following an engine failure the responsibility for the accident might be considered to be equally divided between the pilot and the power plant, in which case 50 percent would be charged to "Personnel" and 50 percent to "Material." If the responsibility for the accident rested largely upon the pilot, "Personnel" would be charged with 60, 70, or 80 percent of the accident, or even more, depending upon the degree of responsibility decided upon. Conversely, in the above cases "Material" and "Miscellaneous" would be charged with a total of 40, 30, or 20 percent of the accident. This same division of responsibility might be carried out under "Personnel"

or other subheads. However, in the particular case cited "Errors of pilot" would be the only division of "Personnel" which could be charged with this accident. If 80 percent of the accident were charged to "Personnel" in the above instance, then 80 percent of the accident would be charged to "Errors of pilot." Then, assuming that the responsibility for such piloting error rested jointly upon error of judgment and poor technique, a still further subdivision would be made and 40 percent of the accident would be charged to "Error of judgment" and 40 percent to "Poor technique." Thus the factors of each crash could be traced down to the last subdivision under any heading and weighted in accordance with their importance.

CLASSIFICATION OF ACCIDENTS

For the purpose of comparative study aircraft accidents may be divided into groups of accidents of the same general characteristics. Accident prevention must be regarded as the primary purpose of aircraft accident study. Studies of accident causes point out needed remedies more clearly when they are supplemented by certain studies based upon the nature and results of the accident.

For example, in both bad landings and tail spins the principal cause is usually errors of the pilot. Statistics based upon the study of causes merely show that pilots' errors are responsible for more than half of all accidents, and the formulation of remedies for the situation appears difficult. If, however, the same accidents are classified according to their nature and results, it is found that the tail spin is the kind of accident that is by far the most prevalent among those which produce fatal consequences. It is apparent that new designs which decrease the tendency of airplanes to spin, or new training methods which increase the ability of pilots to avoid falling into spins and to recover from them quickly, will have a marked influence toward the prevention of fatal accidents.

Likewise, the study based upon nature and results indicates, in the case of collisions, that this kind of accident is third in importance among those which produce fatal results, and that these accidents are much more prevalent during winter months than in summer; and while remedies are not so obvious as in the case of tail spins some lines of attack immediately suggest themselves.

The following classifications for study of accidents according to their nature are recommended:

I. NATURE OF THE ACCIDENT

Under this head accidents are classified according to the type of accident which occurs.

1. *Class A—Collisions in full flight with other aircraft.*—This includes collisions with airplanes, balloons, or other aircraft while the colliding aircraft is at flying speed or at an altitude which permits free maneuvering.

It excludes collisions on the ground while taxiing, taking off, or landing. (See classes F and G.)

2. *Class B—Collisions in full flight with objects other than aircraft.*—This includes collisions while at flying speed and with engine functioning normally, with birds, towing lines, towed sleeves, trees, poles, wires, houses, mountain sides, or other objects. It includes collisions with the earth or water by diving. It excludes collisions on the ground while taxiing, taking off, or landing. It excludes accidents to an aircraft caused by parts of the same aircraft becoming detached in flight and flying back or striking other parts of the aircraft. (See classes F and G.)

3. *Class C—Spins or stalls following engine failure.*—This includes spins, stalls, and all collisions with the earth while the airplane is out of control due to loss of flying speed following engine failure.

4. *Class D—Spins or stalls without engine failure.*—This includes spins, stalls, and all collisions with the earth while the airplane is out of control following loss of flying speed, with the engine functioning normally. It includes spins due to defective handling qualities of the airplane.

5. *Class E—Forced landings.*—This covers accidents while making landings necessitated by conditions which could not be overcome while in flight.

Class E (1)—Emergency forced landings.—This covers accidents while making landings immediately necessitated by conditions which could not be overcome while in flight.

Class E (2)—Deferred forced landings.—This covers accidents while making landings necessitated by conditions which could not be overcome while in flight and which make continued flight inadvisable but do permit a reasonable time for the selection of a landing area.

6. *Class F—Landing accidents.*—This includes accidents occurring while the pilot is in the act of making a voluntary landing. It excludes forced landings, accidents while examining a field from the air or approaching it for a landing, and carrier, platform, and arresting-gear accidents.

7. *Class G—Take-off accidents.*—This includes accidents occurring between the time of starting the take-off and the time when flying speed permitting normal control has been attained with sufficient altitude to permit free maneuvering.

8. *Class H—Taxiing accidents.*—This includes accidents which occur while the aircraft is being operated as such and is maneuvering under its own power on land or water.

9. *Class I—Fires.*—This includes all accidents in which fires occur while the aircraft is being operated as such. It excludes fires which are the result of collision.

Class I (1)—Fires in the air.—This includes all accidents in which fires occur while the aircraft is being operated as such in the air.

Class I (2)—Fires on the ground.—This includes all accidents in which fires occur while the aircraft is being operated as such on the ground.

NOTE: FIRES AFTER ACCIDENT.—This is a secondary grouping for statistical purposes only, and should not be included under Class I.

10. *Class J—Carrier, platform, and arresting-gear accidents.*—This includes accidents occurring while the aircraft is landing upon or taking off from (1) the deck of a floating aircraft carrier, or (2) a platform intended for the landing and taking off of aircraft, but excludes launching-gear accidents.

11. *Class K—Launching-gear accidents.*—This includes accidents during take-off in which the aircraft is assisted in gaining flying speed by the application of an external force.

12. *Class N—Structural failure.*—This includes all accidents resulting in loss of control of the aircraft, as a result of a failure while in flight of any part of the aircraft structure or engine which is not due to contact with any external object.

13. *Class X—Miscellaneous.*—This includes accidents the nature of which is known but which do not fall into one of the above classifications.

14. *Class Y—Undetermined.*—This includes all accidents concerning the nature of which so little is known that any other classification cannot be intelligently made.

II. INJURY TO PERSONS

Under this head accidents are classified according to the injury suffered by persons.

1. *Class A.*—A "Class A" injury is one resulting in the death of the individual within a period of 90 days.

2. *Class B.*—A "Class B" injury is one resulting in serious injury to the individual. Because of the difficulties of classification, the opinion of a physician should be obtained whenever possible as to whether an injury is severe or minor. When a physician is not available, the following general rules should be followed: Any injury that results in unconsciousness; any fracture of any bone except simple fractures of the fingers and toes; lacerations that involve muscles or cause severe hemorrhage; any injury to any internal organ; or any other injury that it seems probable will incapacitate the individual for more than 5 days should be classed as a severe injury. All other injuries should be classed as minor.

3. *Class C.*—A "Class C" injury is one resulting in only minor injury to the individual.

4. *Class D.*—Any person who experiences an aviation accident with no personal injury shall be classified as "Class D."

NOTE.—The classification of an accident according to injury to persons shall contain a letter for each individual in the aircraft at the time of the accident, the first of these letters representing the pilot of the aircraft. For example, in an accident where the pilot is

killed, one passenger seriously injured, and the remaining passenger escapes with only minor injury the accident would be classified as a Class ABC accident. Had the pilot escaped with minor injury and both passengers been killed, it would have been a Class CAA accident.

III. DAMAGE TO MATERIAL

Under this head accidents are classified according to the amount of damage which occurs to material.

1. *Class A.*—This includes all accidents as a result of which the aircraft is of no further value except for possible salvage of usable parts.

2. *Class B.*—This includes all accidents as a result of which it is necessary to completely overhaul the aircraft before it would be again airworthy.

3. *Class C.*—This includes all accidents as a result of which it is necessary to replace some major assembly of the aircraft before it would be again airworthy, such as a wing, fuselage, undercarriage, tail, or engine.

4. *Class D.*—This includes all accidents resulting in minor and easily repairable damage to the aircraft, such as a broken wheel, bent rudder, bent propeller, broken cylinder, broken oil cooler, etc.

5. *Class E.*—This includes all accidents in which there is no damage to material.

CAUSES OF ACCIDENTS

The following classifications for the study of aircraft accidents according to their causes are recommended:

A. IMMEDIATE CAUSES OF AIRCRAFT ACCIDENTS

The following is a proposed list of immediate standard causes of aircraft accidents, with definitions where considered necessary for clarity.

I. *Personnel.*—This includes all accidents which can be traced to persons accessory to the operation or maintenance of the aircraft, either on the ground or in the air. This does not include accidents due to errors or omissions of personnel charged with the design, manufacture, or overhaul of aircraft.

1. *Errors of Pilot.*—This includes all accidents the responsibility for which rests upon the pilot. The pilot is the actual manipulator of the controls or the individual responsible for their correct manipulation.

(a) *Error of Judgment.*—This includes all accidents resulting from a decision made by the pilot which was not the correct one under existing circumstances.

(b) *Poor Technique.*—This includes all accidents resulting from lack of skill, dexterity, or coordination of the senses in handling aircraft controls, whether traceable to inherent inability to attain such or to infrequent flying, lack of experience in flying, lack of experience in flying under particular conditions or in the particular type of aircraft.

NOTE.—Judgment involves mental activity only for the purpose of arriving at decisions as to the ends to be attained and the general course to be followed.

Technique is the physical expression of the mental decisions which have been made.

See example on page 8.

(c) *Disobedience of Orders.*—This includes all accidents resulting from the violation or disobedience of local or general orders or regulations or provisions of law governing the operation of aircraft, such as low acrobatics, acrobatics in aircraft not to be used for such purposes, or any other type or manner of operation specifically forbidden by orders or regulations issued by competent authority.

(d) *Carelessness or Negligence.*—This includes all accidents resulting from the absence of care on the part of the pilot according to circumstances or the failure to use that degree of care which the circumstances justly demand, either on the ground or in the air, such as failure to make the proper mechanical adjustments necessary for take-off or landing.

(e) *Miscellaneous.*—This includes all accidents resulting from errors of the pilot not accounted for above.

2. *Errors of Other Personnel.*—This includes all accidents the responsibility for which rests upon personnel other than the pilot, such as section leaders, navigators, maintenance crew, operations officers, dispatchers, tower control men, or meteorological and communication personnel.

II. *Material.*—This includes all accidents resulting from failure of the airplane structure, power plant, accessories, and launching and arresting devices, whether traceable to material, faulty design, construction, modification, overhaul, or inspection incident to same.

1. *Power Plant.*—This includes all accidents resulting from failure or malfunctioning of the power plant and all auxiliaries essential to its proper functioning, exclusive of instruments. It includes the following:

- (a) FUEL SYSTEM.
- (b) COOLING SYSTEM.
- (c) IGNITION SYSTEM.
- (d) LUBRICATION SYSTEM.
- (e) ENGINE STRUCTURE.
- (f) PROPELLER AND PROPELLER ACCESSORIES.
- (g) ENGINE CONTROL SYSTEM (THROTTLE ROD, ETC.).
- (h) MISCELLANEOUS.
- (i) UNDETERMINED.

2. *Structural.*—This includes all accidents resulting from failure of the airplane exclusive of the power plant and instruments. It includes the following:

- (a) FLIGHT-CONTROL SYSTEM.
- (b) MOVABLE SURFACES.
- (c) STABILIZING SURFACES; STRUTS, WIRES, AND FITTINGS.
- (d) WINGS; STRUTS, WIRES, AND FITTINGS.
- (e) LANDING GEAR; STRUTS, WIRES, FITTINGS, AND RETRACTING MECHANISM.

N.A.C.A. AIRCRAFT ACCIDENT ANALYSIS FORM																										
CLASSIFICATION OF ACCIDENT NATURE : _____ RESULTS : _____ PERSONNEL (CLASS) : _____ MATERIAL (CLASS) : _____				UNDERLYING CAUSES OF ACCIDENT																						
				ERRORS OF PILOT								MATERIAL														
				LACK OF EXPERIENCE				PHYSICAL AND PSYCHOLOGICAL				FAULTY IN-STRUCTURES		INSPECTION		MATERIALS		DESIGN								
				GENERAL		SPECIAL		DISEASE OR DEFECT		POOR RE-ACTION								ORIGINAL		MODIFICATION						
IMMEDIATE CAUSES OF ACCIDENT				TOTAL	RECENT	TOTAL	RECENT	INHERENT	TEMPORARY	INHERENT	TEMPORARY	OPERATING	MAINTENANCE	MANUFACTURING	OVERHAUL	MAINTENANCE	UNDETERMINED	ORIGINALLY DEFECTIVE	DETERIORATED	UNDETERMINED	STRENGTH (STRUCTURAL)	ARRANGEMENT	AERODYNAMIC	UNDETERMINED	UNDETERMINED	
%		%		%																						
PERSONNEL	ERRORS OF PILOT	ERROR OF JUDGMENT																								
		POOR TECHNIQUE																								
		DISOBEDIENCE OF ORDERS																								
		CARELESSNESS OR NEGLIGENCE																								
		MISCELLANEOUS																								
MATERIAL	ERRORS OF OTHER PERSONNEL																									
	POWER PLANT	FUEL SYSTEM																								
		COOLING SYSTEM																								
		IGNITION SYSTEM																								
		LUBRICATION SYSTEM																								
		ENGINE STRUCTURE																								
		PROPELLER AND PROPELLER ACCESSORIES																								
		ENGINE CONTROL SYSTEM																								
		MISCELLANEOUS																								
	STRUCTURAL	UNDETERMINED																								
		FLIGHT CONTROL SYSTEM																								
		MOVABLE SURFACES																								
		STABILIZING SURFACES; STRUTS, WIRES & FITTINGS																								
		WINGS; STRUTS, WIRES, AND FITTINGS																								
		LANDING GEAR; STRUTS, WIRES, FITTINGS, AND RETRACTING MECHANISM																								
		WHEELS, TIRES & BRAKES																								
		SEAPLANE FLOAT OR HULL; STRUTS, WIRES & FITTINGS																								
		FUSELAGE, ENGINE MOUNT, AND FITTINGS																								
		COWLING, FAIRING & FITTINGS																								
		TAIL WHEEL ASSEMBLY AND SKID																								
		ARRESTING APPLIANCES ON AIRCRAFT																								
		MISCELLANEOUS																								
		UNDETERMINED																								
	HANDLING QUALITIES																									
	INSTRUMENTS																									

- (f) WHEELS, TIRES, AND BRAKES.
- (g) SEAPLANE FLOAT OR HULL; STRUTS, WIRES, AND FITTINGS.
- (h) FUSELAGE, ENGINE MOUNT, AND FITTINGS.
- (i) COWLING, FAIRING, AND FITTINGS.
- (j) TAIL-WHEEL ASSEMBLY AND SKID.
- (k) ARRESTING APPLIANCES ON AIRCRAFT.
- (l) MISCELLANEOUS.
- (m) UNDETERMINED.

3. HANDLING QUALITIES.—This includes all accidents resulting from those peculiar characteristics of certain types of aircraft affecting their controllability while on the ground or in the air, such as marked tendency to ground loop, inability to recover from a spin, etc.

4. INSTRUMENTS.—This includes all accidents resulting from failures of instruments which were essential to operation under the conditions of the flight.

5. LAUNCHING DEVICES.—This includes all accidents resulting from failure or malfunctioning of catapults or other launching devices.

6. ARRESTING DEVICES.—This includes all accidents resulting from failure or malfunctioning of arresting gear not a part of the aircraft.

III. *Miscellaneous*.—This includes all accidents not otherwise accounted for.

1. WEATHER.—This includes all accidents resulting from conditions of the weather which could not reasonably have been foreseen and avoided. (Mention may be made on the chart of contributing weather causes, as fog, gale, ice, hail, snow, rain, lightning, or low visibility.)

2. DARKNESS.—This includes all accidents resulting from conditions due to nightfall which could not reasonably have been foreseen and avoided.

3. AIRPORT OR TERRAIN.—This includes all accidents resulting from conditions of the airport or terrain which could not reasonably have been detected or avoided. (Forced landings should not be charged to airport or terrain unless the accident occurs on an area used for landing and take-off purposes.)

4. OTHER.—This includes all accidents resulting from causes not otherwise accounted for above.

IV. *Undetermined*.

B. UNDERLYING CAUSES OF AIRCRAFT ACCIDENTS

The following is a list of standard underlying causes of aircraft accidents, with definitions where considered necessary for clarity.

I. *Errors of pilot*.—Returning to "Errors of Pilot", paragraph I, subparagraph 1, the subdivisions of this paragraph were made according to the immediate causes of the errors attributed to the pilot, such as an "Error of judgment", "Poor technique", etc. The underlying causes of such errors may frequently be of more interest than the immediate causes themselves. These causes may be defined as those elements which contributed to the pilot's mental and physical equip-

ment at the time of the accident or to the deficiencies which existed in such equipment.

1. LACK OF EXPERIENCE.—This includes all accidents resulting from insufficient personal acquaintance with the actual conditions which had to be met under the circumstances.

(a) LACK OF GENERAL EXPERIENCE.—This includes all accidents resulting from a lack of experience in the general problems of aviation, such as landing, taking off, air work, etc.

(1) Lack of total general experience.—This includes all accidents resulting from a lack of general experience due to the fact that the individual concerned has never engaged in such work for a sufficient period of time to acquire the necessary experience to have avoided such accidents.

(2) Lack of recent general experience.—This includes all accidents resulting from a lack of general ability due to the fact that the individual concerned has too infrequently engaged in general flying activities prior to the accident, and consequently lost the ability he had originally acquired.

(b) LACK OF SPECIAL EXPERIENCE.—This includes all accidents resulting from a lack of experience in special problems of aviation, such as certain features of cross-country flying (which might, for example, require an intimate knowledge of the terrain of a certain section), carrier operations, night flying, instrument flying, etc.

(1) Lack of total special experience.—This includes all accidents resulting from a lack of special experience due to the fact that the individual had never engaged in such special problems for a sufficient period of time to acquire the necessary experience to have avoided such accidents.

(2) Lack of recent special experience.—This includes all accidents resulting from a lack of ability in the special problems due to the fact that the individual concerned has too infrequently engaged in special flying activities prior to the accident, and consequently lost the ability he had originally acquired.

2. PHYSICAL AND PSYCHOLOGICAL CAUSES.—This includes all accidents resulting from a demonstrable disease or defect or poor reaction.

(a) DISEASE OR DEFECT.—This includes all accidents resulting from a disease or defect, demonstrable by physical examination.

(1) Inherent disease or defect.—This includes all accidents resulting from a disease or defect which is not susceptible to remedy within a reasonable period of time, such as defective vision or judgment of distance; unconsciousness; hysterical or epileptic tendency; chronic air sickness; inability to withstand altitude, etc., any of which may lead to overshooting a field, faulty landings, or collision. The history of an individual may often be necessary to determine whether a disease or defect is inherent.

(2) Temporary disease or defect.—This includes all accidents resulting from a disease or defect which is remediable and one which may not be expected to repeat itself with undue frequency in the individual concerned, such as temporary illness, incomplete convalescence, etc.

(b) POOR REACTION.—This includes all accidents which result from no demonstrable disease or defect but from other causes which make the individual react either erroneously or slowly to a situation, such as selecting what is manifestly the poorer of two fields for an emergency landing, persisting on a course when better judgment would indicate that he should land or turn back, etc.

(1) Poor reaction, inherent.—This includes all accidents resulting from causes within this classification which apparently are not susceptible to correction within a reasonable period of time. The history of the individual would be a very important adjunct in determining whether such poor reaction were inherent and its repetition to be frequently expected.

(2) Poor reaction, temporary.—This includes all accidents resulting from causes within this classification which apparently are subject to correction within a reasonable period of time.

II. *Material*.—The underlying causes of material failures should also prove of considerable interest in analyzing accidents.

1. FAULTY INSTRUCTIONS.—This includes all accidents resulting from material failures which are traceable to errors or omissions in the standard instructions covering the use of the material.

(a) FAULTY OPERATING INSTRUCTIONS.—This includes all accidents resulting from material failures which are traceable to the operation of the material in accordance with standard instructions which prove to be incorrect or incomplete, such as instructions governing the use of the mixture control which when carried out are found to damage the engine, instructions governing the proper engine operating temperature which when carried out are found to damage the engine, etc.

(b) FAULTY MAINTENANCE INSTRUCTIONS.—This includes all accidents resulting from material failures which are traceable to the maintenance of the material in accordance with standard instructions which prove to be incorrect or incomplete, such as instructions specifying an improper grade of oil for use in an engine.

2. FAULTY INSPECTION.—This includes all accidents resulting from material failures which are traceable to errors or omissions in the inspection of the material.

(a) FAULTY MANUFACTURING INSPECTION.—This includes all accidents traceable to faulty inspection of material where errors or omissions occurred prior to the receipt of this material by the consumer.

(b) FAULTY OVERHAUL INSPECTION.—This includes all accidents traceable to faulty inspection of material where errors or omissions occurred during overhaul or storage of the material.

(c) FAULTY MAINTENANCE INSPECTION.—This includes all accidents traceable to faulty inspection of material where errors or omissions in such inspection occurred after the final delivery of this material to the operating unit.

(d) FAULTY INSPECTION, UNDETERMINED.—This includes all accidents traceable to faulty inspection of material where actual responsibility for the errors or omissions in inspection cannot be definitely placed.

3. FAULTY MATERIALS.—This includes all accidents resulting from material failures which are traceable to defective materials when the defects in materials could not reasonably have been detected and eliminated by a proper system of inspection.

(a) ORIGINALLY DEFECTIVE MATERIALS.—This includes all accidents traceable to faulty materials where the materials contained the defects when originally delivered.

(b) DETERIORATED MATERIALS.—This includes all accidents traceable to faulty materials where the defects of such materials occurred through deterioration after delivery.

(c) FAULTY MATERIALS, UNDETERMINED.—This includes all accidents traceable to faulty materials where it is not possible to determine the actual time or place when the defects first appeared.

4. FAULTY DESIGN.—This includes all accidents resulting from material failures which are traceable to errors or omissions in the design of the material.

(a) FAULTY DESIGN, ORIGINAL.—This includes all accidents traceable to faulty design where errors or omissions in such design occurred in the original design of the material, or in the course of changes in such design made prior to the final acceptance of the material by the operator.

(1) Faulty original design, structural strength.

(2) Faulty original design, arrangement.

(3) Faulty original design, aerodynamic.

(4) Faulty original design, undetermined.

(b) FAULTY DESIGN, MODIFICATION.—This includes all accidents traceable to faulty design where errors or omissions in such design occurred in modifications to the original design of the material made subsequent to the final acceptance of the material by the operator.

5. UNDETERMINED MATERIAL FAILURE.—This includes all accidents from material failures the exact cause of which cannot be determined.

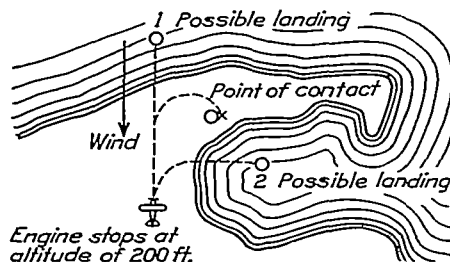
ALLOCATION OF ACCIDENTS

In compiling statistics an accident should be allocated to the service or organization having jurisdiction over or control of the operation of the aircraft at the time of the accident. In the case of collisions the accident itself should be analyzed as a single accident, but should be carried statistically by each of the organizations involved.

Injuries and fatalities should be allocated according to the aircraft in which they occur.

DESCRIPTION AND TYPICAL ANALYSIS OF AN ACCIDENT

Pilot John Doe was flying in a seaplane at an altitude of 200 feet over a point of land between a bay and the open sea when the engine stopped. Pilot Doe had an opportunity to land either directly into the wind in the open sea or cross wind in the bay. He started to land in the ocean but at 100 feet altitude he changed his mind and attempted to turn so as to land in the bay. In turning, Doe held the nose of the seaplane up, stalled it, and spun into the land. The seaplane was demolished, the pilot was seriously injured, and the passenger was killed.



Doe, according to his record, was an experienced aviator with 30 hours' flying during the preceding month and with recent experience in stunting airplanes.

Examination of the engine showed that one of the teeth in the magneto timing gear had stripped, the broken tooth having been drawn into the other teeth, causing the eventual stripping of all teeth. The original break was determined to be a visible hardening crack.

The NATURE of this accident is class C—tail spin following engine failure, as defined on page 3. The classification according to RESULTS is Personnel, class BA (pp. 3 and 4); Material, class A. (p. 4).

In analyzing this accident the IMMEDIATE CAUSE is charged, as indicated on the analysis chart, as 75 percent "Personnel" and 25 percent "Material", for the reason that the account of the accident shows that the pilot had two chances to make a safe landing and took advantage of neither of them. Considering the 75 percent which is charged to "Personnel", it is obvious that this is not chargeable to "Errors of other personnel", so that the whole weight, 75 percent, must be placed under "Errors of pilot." It appears that the errors of the pilot involved both errors of judgment and poor technique. He first decided to land straight ahead in the ocean, which was a proper decision. Then, after reaching an altitude at which turning without power is generally considered dangerous, he decided to turn and land in the bay. This was an error and showed poor judgment. Poor technique was displayed in the execution of this decision in that the pilot continued to pull the nose up, still further stalling the seaplane, when he should have sensed the approaching stall. It is considered that a charge of 35 percent to "Error of

judgment" and 40 percent to "Poor technique" represents as near an approximation as can be reached in this case.

UNDERLYING CAUSES

On analysis of UNDERLYING CAUSES it would appear that the "Error of judgment" and "Poor technique" were both due to a "Temporary poor reaction" with a strong possibility of such "Poor reaction" being "Inherent" rather than "Temporary." However, in the absence of a history of the individual this would have to be classified as "Temporary."

Considering the 25 percent charged to "II. Material", the entire 25 percent obviously should be assigned to "1. Power-plant failure", in the second order of subdivision, and again in the third order of subdivision the entire 25 percent should be charged to "(c) Ignition system."

The underlying cause of this material failure is unquestionably faulty manufacturing and accordingly on the cross analysis it would be placed under the head of "Manufacturing inspection."

INTERPRETATION OF DEFINITIONS AND METHODS

As was anticipated, questions have arisen regarding the proper interpretation of the definitions and the methods to be followed in using the proposed method of analysis. These questions have generally been referred to the committee for opinions or the interpretations followed have been communicated for approval. In this manner there has been established a sort of approved procedure.

An early criticism was the effect of the personal factor on the weights to be assigned to the various causes of an accident. That the average obtained from a considerable number of cases can not be far off is shown by the results from a test conducted by the original special committee, but not mentioned in its report. Six accidents were reported in identical form to each member of the committee and were analyzed independently by him. The percentages assigned the various causes were then averaged and the averages were compared with the individual ratings. Every member was willing to accept the average values as a fair analysis of the various accidents, and the differences between the values assigned by the individuals and averages were remarkably small.

CONCLUSION

The Committee on Aircraft Accidents believes that the practical value of the accident analysis chart prepared by the Committee on Aircraft Accidents, and the importance of the information which may be obtained from the use of this chart, have been clearly demonstrated in its use in service in the War, Navy, and Commerce Departments.

N.A.C.A. AIRCRAFT ACCIDENT ANALYSIS FORM																									
CLASSIFICATION OF ACCIDENT NATURE: <u>CLASS C-TAIL SPIN</u> <u>FOLLOWING ENGINE FAILURE</u> RESULTS: _____ PERSONNEL (CLASS) <u>BA</u> MATERIAL (CLASS) <u>A</u>				UNDERLYING CAUSES OF ACCIDENT																					
				ERRORS OF PILOT								MATERIAL													
				LACK OF EXPERIENCE		PHYSICAL AND PSYCHOLOGICAL		FAULTY IN-STRUCTURES	INSPECTION		MATERIALS		DESIGN				UNDETERMINED								
													ORIGINAL												
		GENERAL		SPECIAL		DISEASE OR DEFECT	POOR REACTION	OPERATING	MAINTENANCE	MANUFACTURING	OVERHAUL	MAINTENANCE	UNDETERMINED	ORIGINALLY DEFECTIVE	DETERIORATED	UNDETERMINED	STRENGTH (STRUCTURAL)	ARRANGEMENT	AERODYNAMIC	UNDETERMINED					
		TOTAL	RECENT	TOTAL	RECENT																INHERENT	TEMPORARY	INHERENT	TEMPORARY	
IMMEDIATE CAUSES OF ACCIDENT:																									
%		%		%																					
75	PERSONNEL	75	ERRORS OF PILOT	35	ERROR OF JUDGMENT															35					
				40	POOR TECHNIQUE															40					
					DISOBEDIENCE OF ORDERS																				
					CARELESSNESS OR NEGLIGENCE																				
					MISCELLANEOUS																				
					ERRORS OF OTHER PERSONNEL																				
25	MATERIAL	25	POWER PLANT		FUEL SYSTEM																				
					COOLING SYSTEM																				
				25	IGNITION SYSTEM															25					
					LUBRICATION SYSTEM																				
					ENGINE STRUCTURE																				
					PROPELLER AND PROPELLER ACCESSORIES																				
					ENGINE CONTROL SYSTEM																				
					MISCELLANEOUS																				
			UNDETERMINED																						
			STRUCTURAL		FLIGHT CONTROL SYSTEM																				
					MOVABLE SURFACES																				
					STABILIZING SURFACES; STRUTS, WIRES & FITTINGS																				
					WINGS; STRUTS, WIRES, AND FITTINGS																				
					LANDING GEAR; STRUTS, WIRES, FITTINGS, AND RETRACTING MECHANISM																				
					WHEELS, TIRES & BRAKES																				
					SEAPLANE FLOAT OR HULL; STRUTS, WIRES & FITTINGS																				
					FUSELAGE, ENGINE MOUNT, AND FITTINGS																				
					COWLING, FAIRING & FITTINGS																				
					TAIL WHEEL ASSEMBLY AND SKID																				
					ARRESTING APPLIANCES ON AIRCRAFT																				
					MISCELLANEOUS																				
					UNDETERMINED																				
					HANDLING QUALITIES																				
					INSTRUMENTS																				
	LAUNCHING DEVICES																								
	ARRESTING DEVICES																								
MISCELLANEOUS		WEATHER																							
		DARKNESS																							
		AIRPORT OR TERRAIN																							
		OTHER																							
UNDETERMINED																									

RECOMMENDED BY
 COMMITTEE ON AIRCRAFT ACCIDENTS
 JUNE 22, 1936
 APPROVED BY
 EXECUTIVE COMMITTEE
 NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
 JUNE 23, 1936

As a result of experience, there have been introduced into the present report some minor changes in definitions and nomenclature, which changes, however, are in conformity with the classifications already set up.

The committee has given careful consideration to the physiological and psychological problems involved in the piloting of aircraft as having an important bearing on the number and types of accidents which occur.

The report represents the experience of the committee and of the three departments concerned in the

study of aircraft accidents up to the present time. The study of aircraft accidents for the purpose of analyzing them in such a manner as to assist in reducing their frequency and severity is a task which can never be completed, but must be continued in step with the progress of the art.

Respectfully submitted.

COMMITTEE ON AIRCRAFT ACCIDENTS,
EDWARD P. WARNER, *Chairman*.

WASHINGTON, D. C., *June 22, 1936*.

AERONAUTIC SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

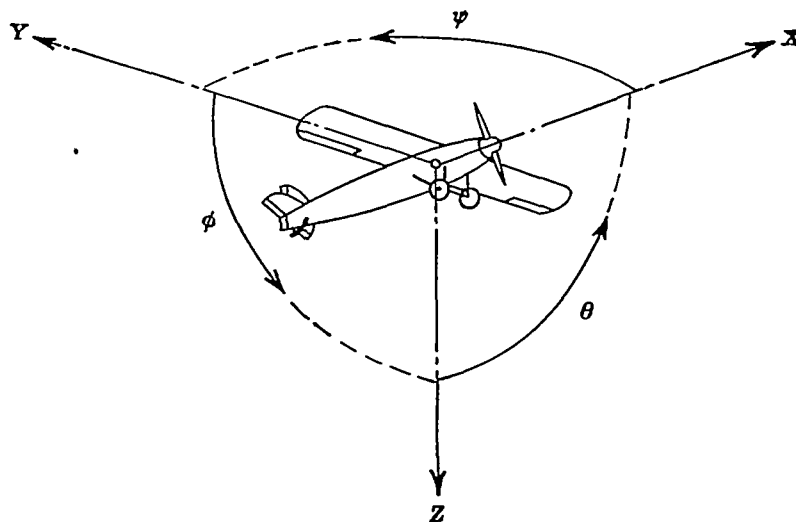
	Symbol	Metric		English	
		Unit	Abbrevia- tion	Unit	Abbrevia- tion
Length.....	l	meter.....	m	foot (or mile).....	ft. (or mi.)
Time.....	t	second.....	s	second (or hour).....	sec. (or hr.)
Force.....	F	weight of 1 kilogram.....	kg	weight of 1 pound.....	lb.
Power.....	P	horsepower (metric).....		horsepower.....	hp.
Speed.....	V	{kilometers per hour..... meters per second.....	{k.p.h. m.p.s.	{miles per hour..... feet per second.....	{m.p.h. f.p.s.

2. GENERAL SYMBOLS

W ,	Weight = mg	ν ,	Kinematic viscosity
g ,	Standard acceleration of gravity = 9.80665 m/s ² or 32.1740 ft./sec. ²	ρ ,	Density (mass per unit volume)
m ,	Mass = $\frac{W}{g}$		Standard density of dry air, 0.12497 kg-m ⁻⁴ -s ² at 15° C. and 760 mm; or 0.002378 lb.-ft. ⁻⁴ sec. ²
I ,	Moment of inertia = mk^2 . (Indicate axis of radius of gyration k by proper subscript.)		Specific weight of "standard" air, 1.2255 kg/m ³ or 0.07651 lb./cu.ft.
μ ,	Coefficient of viscosity		

3. AERODYNAMIC SYMBOLS

S ,	Area	i_w ,	Angle of setting of wings (relative to thrust line)
S_w ,	Area of wing	i_s ,	Angle of stabilizer setting (relative to thrust line)
G ,	Gap	Q ,	Resultant moment
b ,	Span	Ω ,	Resultant angular velocity
c ,	Chord	$\frac{\rho V l}{\mu}$,	Reynolds Number, where l is a linear dimension (e.g., for a model airfoil 3 in. chord, 100 m.p.h. normal pressure at 15° C., the corresponding number is 234,000; or for a model of 10 cm chord, 40 m.p.s. the corresponding number is 274,000)
\bar{S} ,	Aspect ratio	C_p ,	Center-of-pressure coefficient (ratio of distance of c.p. from leading edge to chord length)
V ,	True air speed	α ,	Angle of attack
q ,	Dynamic pressure = $\frac{1}{2}\rho V^2$	ϵ ,	Angle of downwash
L ,	Lift, absolute coefficient $C_L = \frac{L}{qS}$	α_o ,	Angle of attack, infinite aspect ratio
D ,	Drag, absolute coefficient $C_D = \frac{D}{qS}$	α_i ,	Angle of attack, induced
D_o ,	Profile drag, absolute coefficient $C_{D_o} = \frac{D_o}{qS}$	α_a ,	Angle of attack, absolute (measured from zero-lift position)
D_i ,	Induced drag, absolute coefficient $C_{D_i} = \frac{D_i}{qS}$	γ ,	Flight-path angle
D_p ,	Parasite drag, absolute coefficient $C_{D_p} = \frac{D_p}{qS}$		
C ,	Cross-wind force, absolute coefficient $C_C = \frac{C}{qS}$		
R ,	Resultant force		



Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Sym- bol		Designation	Sym- bol	Positive direction	Designa- tion	Sym- bol	Linear (compo- nent along axis)	Angular
Longitudinal	X	X	Rolling	L	Y→Z	Roll	φ	u	p
Lateral	Y	Y	Pitching	M	Z→X	Pitch	θ	v	q
Normal	Z	Z	Yawing	N	X→Y	Yaw	ψ	w	r

Absolute coefficients of moment

$$C_l = \frac{L}{qbS}$$

(rolling)

$$C_m = \frac{M}{qcS}$$

(pitching)

$$C_n = \frac{N}{qbS}$$

(yawing)

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter

p, Geometric pitch

p/D, Pitch ratio

V', Inflow velocity

V_s, Slipstream velocity

T, Thrust, absolute coefficient $C_T = \frac{T'}{\rho n^2 D^4}$

Q, Torque, absolute coefficient $C_Q = \frac{Q}{\rho n^2 D^5}$

P, Power, absolute coefficient $C_P = \frac{P}{\rho n^3 D^5}$

C_s, Speed-power coefficient $= \sqrt[5]{\frac{\rho V^5}{P n^3}}$

η, Efficiency

n, Revolutions per second, r.p.s.

Φ, Effective helix angle $= \tan^{-1} \left(\frac{V}{2\pi r n} \right)$

5. NUMERICAL RELATIONS

1 hp. = 76.04 kg-m/s = 550 ft-lb./sec.

1 metric horsepower = 1.0132 hp.

1 m.p.h. = 0.4470 m.p.s.

1 m.p.s. = 2.2369 m.p.h

1 lb. = 0.4536 kg.

1 kg = 2.2046 lb.

1 mi. = 1,609.35 m = 5,280 ft.

1 m = 3.2808 ft.